



DECLARATION

I, Jun OKAMOTO, residing at 2023, Takao-machi, Hachioji-shi, Tokyo, Japan, do hereby certify that I am conversant with the English and Japanese languages and am a competent translator thereof. I further certify that to the best of my knowledge and belief the attached English translation is a true and correct translation made by me of U.S. Provisional Patent Application No. 60/440,385 filed on January 16, 2003.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 17th day of February, 2004

A handwritten signature in cursive script, appearing to read "Jun Okamoto", written over a horizontal line.

Jun OKAMOTO



[Document Name]

Specification

[Title of the Invention]

Improved Metal Coated Cubic
Boron Nitride Abrasive Grain,
Production Method Thereof and
Resin Bond Grindstone

[Detailed Description of the Invention]

[0001]

[Technical Field to Which the Invention Pertains]

The present invention relates to metal-coated cubic boron nitride abrasive grains. More particularly, the present invention relates to metal-coated cubic boron nitride abrasive grains which are produced by forming crack-like grooves on the surfaces of cubic boron nitride abrasive grains, and then forming a metallic coating layer on the grain surfaces such that the metallic coating layer enters the grooves; i.e., the layer intrudes into the abrasive grains, to thereby enhance adhesion between the abrasive grains and the metallic coating layer; to a method for producing the metal-coated cubic boron nitride abrasive grains; and to a resin bond grinding wheel incorporating the metal-coated cubic boron nitride abrasive grains.

[0002]

[Background Art]

Conventionally, cubic boron nitride (hereinafter may be referred to simply as "cBN") grains have been employed as abrasive grains for producing, for example, grinding wheels and coated abrasives, since cBN exhibits hardness second only to diamond, chemical stability, and, as compared with diamond,

excellent stability against an iron workpiece. Abrasive grains of cBN are produced through treatment of hexagonal boron nitride (hBN) in the presence of a catalytic substance under high-temperature, high-pressure conditions (about 4 to about 6 GPa, about 1,400 to about 1,600°C), under which cBN is thermally stable.

The thus-produced cBN abrasive grains, which are blocky and assume a relatively spherical shape, are employed in, for example, electroplated grinding wheels and metal bond grinding wheels.

[0003]

In general, when abrasive grains are employed in a grinding wheel, the grains are supported by an appropriate matrix, and the thus-supported grains are mounted in a grinding wheel main body. The abrasive grains are supported by means of surrounding the grains with a matrix material. This mounting can be carried out by means of a simple, practical method, so long as the abrasive grains are exposed such that the grains exhibit grinding ability, and the bonding strength of the matrix to the abrasive grains is enhanced such that the ability of the matrix to mechanically hold the grains is not lowered. As such a matrix material, a variety of metals such as titanium (Ti) are widely employed. When the grinding wheel is continuously used for grinding, the matrix surrounding the abrasive grains undergoes wear, and the ability of the matrix to support the abrasive grains is lowered, leading to falling of the abrasive grains from

the matrix. In view of the foregoing, in order to lengthen the service life of a grinding wheel exhibiting excellent grinding performance, various methods for supporting abrasive grains have been proposed.

[0004]

For example, there has been proposed a method in which the surfaces of cubic boron nitride grains are mechanically roughened through stirring, or roughened through high-temperature oxidation by use of potassium dichromate or potassium nitrate, and the thus-roughened grain surfaces are coated with a metal such as titanium (Ti), tungsten (W), molybdenum (Mo), or niobium (Nb) (See, for example, Patent Document 1).

The patent document disclosing this method describes that the bonding strength between the cubic boron nitride grains and the metallic coating layer serving as a matrix is enhanced and that even when the resultant abrasive grains are buried in a grinding wheel, falling of the abrasive grains is suppressed.

Also, there has been proposed a method in which a metallic coating layer serving as a matrix is formed of a double-layer structure (see, for example, Patent Document 2). In this method, an interstitial metallic layer, serving as a first layer, is formed on cubic boron nitride grains by means of, for example, salt bath deposition, chemical vapor deposition, or physical vapor deposition, to thereby chemically bond the grains to the first layer, and

subsequently a metallic layer, serving as a second layer, is formed on the first layer by means of, for example, electroless deposition, electrolytic deposition, or vapor deposition. This patent document describes that both the first and second layers can be formed of titanium (Ti), zirconium (Zr), hafnium (Hf), vanadium (V), niobium (Nb), tantalum (Ta), chromium (Cr), molybdenum (Mo), or an alloy, carbide, nitride, boride, or oxide of such a metal, and the second layer can be formed of nickel (Ni). According to this patent document, desirably, the thicknesses of the first layer and the second layer are 0.1 to 500 μm and 5 μm or more, respectively.

According to the disclosure of this patent document, a thick coating film (matrix) can be readily formed by means of this method, and the coating film (matrix) strongly bonds to the abrasive grains and exhibits excellent performance for supporting the grains.

[0005]

[Patent Document 1]

Japanese Patent Application Laid-Open (*kokai*) No. 5-194939

[Patent Document 2]

Japanese Patent Application Laid-Open (*kokai*) No. 4-185667

[0006]

[Problems to be Solved by the Invention]

However, the aforementioned methods involve problems in

that an intricate process is required for forming a coating film serving as a matrix, leading to long production time and high production cost.

Objects of the present invention are to provide a method for forming a metallic coating layer serving as a matrix within a short period of time and at low cost; to provide metal-coated cubic boron nitride abrasive grains in which bonding strength between abrasive grains and a metallic coating layer is enhanced; and to provide a grinding wheel incorporating the abrasive grains, which exhibits excellent grinding performance and has a long service life.

[0007]

[Means for Solving the Problems]

In order to solve the aforementioned problems, the present invention provides:

- (1) A cubic boron nitride abrasive grain characterized by having, on its surface, a crack-like groove;
- (2) A cubic boron nitride abrasive grain according to (1), wherein the crack-like groove has a portion in which the ratio of the width of the portion to the depth thereof is less than 1 as viewed in cross section;
- (3) A metal-coated cubic boron nitride abrasive grain comprising a cubic boron nitride abrasive grain, and a metallic coating layer formed on the surface of the grain, wherein the metallic coating layer intrudes into the cubic boron nitride abrasive grain;
- (4) A metal-coated cubic boron nitride abrasive grain

according to (3), wherein a region of the abrasive grain into which the metallic coating layer intrudes has a portion in which the ratio of the width of the portion to the depth thereof is less than 1 as viewed in cross section;

(5) A method for producing metal-coated cubic boron nitride abrasive grains, comprising thermally treating cubic boron nitride abrasive grains at a temperature of at least 900°C, to thereby form crack-like grooves on the surfaces of the cubic boron nitride abrasive grains; and subsequently subjecting the resultant abrasive grains to metal coating treatment;

(6) A method for producing metal-coated cubic boron nitride abrasive grains according to (5), wherein the upper limit of the thermal treatment temperature is a temperature of 1,300°C or lower in the case where thermal treatment is carried out in air, and is 1,600°C or lower in the case where thermal treatment is carried out in a non-oxidative atmosphere; and

(7) A resin bond grinding wheel characterized by comprising a metal-coated cubic boron nitride abrasive grain as recited in claim 3 or 4.

Through the aforementioned means, a metallic coating layer serving as a matrix is caused to intrude into cBN abrasive grains, to thereby enhance the bonding strength between the metallic coating layer and the cBN abrasive grains. When a resin bond grinding wheel is produced from the metal-coated cBN abrasive grains, the resin bond grinding wheel exhibits excellent grinding performance, since falling

of the cBN abrasive grains from the grinding wheel is suppressed during use of the grinding wheel for grinding.

[0008]

The present inventors have performed extensive studies on a method for enhancing the bonding strength between cBN abrasive grains and a metallic coating layer. In the course of these studies, the present inventors attempted to perform metal coating on cBN abrasive grains having, on their surfaces, depressions formed through various means. Specifically, metal coating was performed on cBN abrasive grains having, on their surfaces, depressions formed by means of etching employing a chemical; on cBN abrasive grains having, on their surfaces, small grooves formed by means of laser beam machining; and on cBN abrasive grains having, on their surfaces, crack-like grooves formed by means of thermal treatment of the grains in air at 1,050°C.

For comparison, the surfaces of cBN abrasive grains were coated with metallic Ti by means of the method described in Patent Document 1. Coating with metallic Ti was performed by means of the salt bath method. The bath temperature was regulated to 800°C, which falls within a bath temperature range disclosed in Patent Document 1 of 800 to 1,500°F (426 to 815°C).

Furthermore, conventional metal-coated cBN abrasive grains having, on their surfaces, no depressions or grooves were qualitatively evaluated in terms of bonding strength between the grains and the metallic coating layer.

The bonding strength was evaluated through the following procedure: each type of the above-prepared metal-coated cBN abrasive grains was placed in a small-sized iron-made pot filled with steel balls having a diameter of 5 mm; the pot was rotated for a predetermined period of time; the resultant metal-coated cBN abrasive grains were removed from the pot and then observed under a microscope; and the state of bonding between the metallic coating layer and the cBN abrasive grains was evaluated.

[0009]

The results revealed that, in the case of the metal-coated cBN abrasive grains having grooves formed by means of laser beam machining or the metal-coated cBN abrasive grains having crack-like grooves formed by means of thermal treatment, the bonding strength between the cBN abrasive grains and the metallic coating layer is comparable to that in the case of the cBN abrasive grains coated with metallic Ti by means of the method disclosed in Patent Document 1. Meanwhile, in the case of the metal-coated cBN abrasive grains having depressions formed by means of etching employing a chemical, some exfoliation of the metallic coating layer occurred, and the bonding strength between the cBN abrasive grains and the metallic coating layer—although higher than that in the case of the conventional metal-coated cBN abrasive grains having no depressions nor grooves on their surfaces—was found to be insufficient as compared with the case of the other metal-

coated cBN abrasive grains.

Observation of the cross section of the metal-coated abrasive grains revealed that the metallic coating layer, which was formed on the cBN abrasive grains having, on their surfaces, grooves or depressions, intruded into the cBN abrasive grains. In the case of the metal-coated cBN abrasive grains having depressions formed by means of etching employing a chemical, in most of the depressions into which the metallic coating layer intruded, the ratio of the width to the depth was found to be greater than 1 as viewed in the cross sections of the depressions. In contrast, in the case of the metal-coated cBN abrasive grains having grooves formed by means of laser beam machining or the metal-coated cBN abrasive grains having crack-like grooves formed by means of thermal treatment, the ratio of the width to the depth of a groove (or depression) formed on the grain surfaces was found to be less than 1.

[0010]

On the basis of the above results, the present inventors have found that when cBN abrasive grains are thermally treated to thereby form, on their surfaces, crack-like grooves in which the ratio of the width to the depth thereof is less than 1, and then metal coating is performed on the resultant abrasive grains, there are produced metal-coated cubic boron nitride abrasive grains exhibiting high bonding strength between the abrasive grains and the metallic coating layer. The present invention has been accomplished

on the basis of this finding.

The present invention will next be described in more detail.

[0011]

[Modes for Carrying Out the Invention]

Prior to metal coating, target grooves are formed on the surfaces of cBN grains such that the ratio of the width to the depth of each of the grooves is less than 1. The grooves may be formed by means of laser beam machining, but this method requires high operation cost and cannot be applied to practical production. In contrast, a method for forming crack-like grooves on the surfaces of cBN grains through thermal treatment is practical and preferable, from the viewpoint of production cost.

Next will be described a specific method for forming crack-like grooves on the surfaces of cBN grains through thermal treatment. Thermal treatment is carried out by heating cBN grains at a temperature of 900°C or higher. Thermal treatment may be carried out in air or in a non-oxidative atmosphere such as a vacuum atmosphere, a nitrogen gas atmosphere, or an inert gas atmosphere.

In the case where thermal treatment is carried out in air, when cBN abrasive grains are heated at a temperature of 900°C or higher, sufficient amounts of crack-like grooves can be formed on the surfaces of the grains. When the heating temperature exceeds 1,300°C, the cBN abrasive grains undergo considerable degradation. Therefore, thermal treatment is

carried out at 900°C to 1,300°C, preferably at 1,250°C or lower. In the case where the abrasive grains are formed into agglomerates through thermal treatment, when the agglomerates are subjected to acid treatment with, for example, hydrochloric acid, the agglomerates can be readily broken into grains.

In the case where thermal treatment is carried out in a non-oxidative atmosphere such as a vacuum atmosphere, a nitrogen gas atmosphere, or an inert gas atmosphere, since degradation of cBN abrasive grains is suppressed, the upper limit of the thermal treatment temperature can be increased to 1,600°C. The higher the temperature at which thermal treatment is carried out, the shorter the time required for forming target grooves.

[0012]

In each of the crack-like grooves formed through the aforementioned thermal treatment, as shown in Fig. 5, the width (w) is 0.3 to 3.0 μm , and the depth (d) is about 3.0 to about 20 μm ; i.e., the ratio of the width (w)/the depth (d) is 1 or less. Fig. 1 schematically shows the appearance of a cBN abrasive grain which has not undergone thermal treatment. A cBN abrasive grain 10 basically has an octahedral structure including (111) planes 1 serving as primary planes, but, in most grain crystals, each of the planes 1 is surrounded by flat growth planes 2. Industrially produced cBN abrasive grains contain, in addition to nearly perfect crystal grains, deformed grains. Fig. 2 schematically shows the appearance

of a cBN abrasive grain 10 which has undergone thermal treatment. Crack-like grooves 3 are formed on the surfaces of (111) planes 1 constituting the octahedral structure. As shown in Fig. 2, the crack-like grooves 3 start from growth planes 2 toward a center portion of each of the (111) planes 1.

A metallic coating layer (to become a matrix) formed on the surface of a cBN abrasive grain deeply intrudes into a groove in which the ratio of the width (w)/the depth (d) is 1 or less, and the coating layer securely holds the grain. Therefore, the metallic coating layer strongly bonds to the abrasive grain. When a groove is formed by means of etching employing a chemical solution, the width of the thus-formed groove increases toward the surface of a cBN grain as viewed in the cross section of the groove, since, in general, the etching rate in a depth direction is equal to that in a direction perpendicular to the depth direction. When an attempt is made to form a deep groove by means of etching, etching in a horizontal direction also proceeds, and therefore, the resultant groove becomes a shallow depression as viewed in cross section. Such a groove formed through etching exhibits poor anchoring effect. Fig. 8 is an SEM image showing the surface of a cBN abrasive grain which has undergone thermal treatment in air at 600°C with the surface being coated with caustic soda, followed by etching. As shown in Fig. 8, matte portions represent shallow grooves formed on the grain surface.

A metallic coating material insufficiently intrudes into a groove in which the ratio of the width (w)/the depth (d) is 1 or more, and thus the resultant metallic coating layer fails to exhibit satisfactory bonding strength to a cBN abrasive grain. Therefore, in each of grooves formed on a cBN abrasive grain, the ratio of the width (w)/the depth (d) must be 1 or less.

[0013]

After completion of formation of crack-like grooves on the surfaces of cubic boron nitride grains, the surfaces are coated with a metallic coating layer serving as a matrix. No particular limitations are imposed on the metal coating method, and any known coating method may be employed. For example, there may be employed a method disclosed in Japanese Patent Publication (*kokoku*) No. 3-73426, in which a metallic coating layer having a three-layer structure including a nickel electroless plating layer, a cobalt electroplating layer or a cobalt electroless plating layer, and a nickel electroless plating layer is formed.

Fig. 3 is a perspective view showing a cBN abrasive grain having, on its surface, crack-like grooves 3, the surface of the grain being coated with a metallic coating layer. Fig. 4 is schematic cross-sectional view of the cBN abrasive grain of Fig. 3, as taken along line A-A'. As shown in Fig. 4, a metallic coating layer 5 formed on the surface of a cBN abrasive grain 10 reaches a deep portion of each of the crack-like grooves 3 formed on the grain surface; i.e.,

the layer 5 intrudes into the cBN abrasive grain 10. Fig. 5 is an enlarged view showing a region of the abrasive grain into which the metallic coating layer 5 intrudes. As shown in Fig. 5, when the ratio of the width (w)/the depth (d) of the crack-like groove 3 is 1 or less, by virtue of the anchoring effect of the metallic coating layer 5 which intrudes into the crack-like groove 3, the metallic coating layer 5 strongly bonds to the surface of the cBN abrasive grain 10.

[0014]

A resin, a filler, or a similar material is added to the above-produced metal-coated cubic boron nitride abrasive grains, and the resultant mixture is solidified, to thereby produce a grinding stone. Examples of the resin which may be employed include a phenolic resin, an epoxy resin, and an unsaturated polyester resin. The amount of the resin to be added is about 25 to about 60 wt.%. Examples of the filler which may be employed include alumina, magnesia, silica, and mullite. A necessary amount of such a filler is added. The metal-coated cubic boron nitride abrasive grains (about 10 wt.% to about 50 wt.%) are mixed with such a resin or filler, and the resultant mixture is subjected to pressure molding. In the course of molding, when a solid lubricant such as molybdenum disulfide, graphite, graphite fluoride, or hexagonal boron nitride is employed, wear between the resultant grinding wheel and a workpiece is lowered, whereby generation of heat is prevented, and the service life of the

grinding wheel is lengthened. The amount of the solid lubricant to be added is preferably about 5 to about 10%. In order to improve adhesion between the metal-coated cubic boron nitride abrasive grains and the resin, effectively, a coupling agent is applied in advance to the abrasive grains.

The aforementioned raw materials are uniformly mixed together, and the resultant mixture is charged into a predetermined mold, followed by pressure molding at a predetermined temperature and a predetermined pressure. Thereafter, the resultant product is removed from the mold, and then further heated to cure the resin, to thereby produce a grinding stone. Molding of the grinding stone may be carried out by means of a process in which the grinding stone is joined to a base of any predetermined shape. Through this process, the grinding stone and the base are united to form a grinding wheel.

[0015]

[Examples]

The present invention will next be described in more detail by way of Examples.

(Example 1 and Comparative Example 1)

Cubic boron nitride (SBN-B: registered trademark, product of Showa Denko K.K., 100/120 grade) was thermally treated in air at 1,050°C for one hour. As shown in an SEM image of Fig. 6, grooves, each having a width (w) of 0.3 to 3.0 μm and a depth (d) of 3.0 to 20 μm , wherein the ratio of the width (w)/the depth (d) is 1 or less, were formed in the

surface of each of the resultant cubic boron nitride grains. Subsequently, the cubic boron nitride grains were subjected to boiling by use of aqua regia, followed by acid removal and drying. Thereafter, by means of the method disclosed in Japanese Patent Publication (*kokoku*) No. 3-73426, the resultant boron nitride grains were coated with a metallic coating layer having a three-layer structure including a nickel electroless plating layer, a cobalt electroless plating layer, and a nickel electroless plating layer. Fig. 7 is an SEM image showing the state where a white metallic coating layer intrudes into grooves formed on the surface of a black cubic boron nitride abrasive grain.

For comparison, cubic boron nitride grains which had not undergone thermal treatment were prepared, and the cubic boron nitride grains were coated with a metallic coating layer of three-layer structure similar to that employed in the above Example.

A resin bond grinding wheel was produced from each of the above-produced two types of cubic boron nitride grains, and the resultant grinding wheel was subjected to grinding test. Table 1 shows the compositional proportions of the grinding wheel. Concentration was regulated to 75. The dimensions of the grinding wheel were regulated to 150 D × 5 U × 3 X × 76.2 H.

[0016]

[Table 1]

	Material	Compositional proportions (vol%)
Abrasive grains	Metal-coated cBN abrasive grains	31.4
Bond	Phenolic resin	58.6
Filler	Electrofused alumina #600	10.0

[0017]

The grinding test was performed under the below-described conditions.

The grinding test was performed by means of a wet-plane traverse grinding method under the following grinding conditions: wheel speed: 1,500 m/min, table speed: 15 m/min, cross feed: 2 mm/pass, infeed: 40 μ m. High-speed tool steel (JIS SKH-51 (HRC = 62 to 64)) was employed as a workpiece. The test results are shown in Table 2. "Grinding ratio" shown in Table 2 is obtained by dividing the volume of workpiece material removed through grinding by the volume of wheel material removed during the course of grinding. The higher the grinding ratio, the better the grinding performance of the grinding wheel. "Grinding power" shown in Table 2 refers to the power of a motor employed for rotating the grinding wheel during the course of grinding. The lower the grinding power, the better the cutting performance (i.e., grinding performance) of the grinding wheel.

[0018]

[Table 2]

Abrasive grains	Comparative Example 1	Example 1
Grinding ratio	146	175
Grinding power (W)	850	930
Number of residual abrasive grains	418	503
Number of voids on metallic coating layer	158	102

[0019]

As shown in Table 2, in the case of the invention grinding wheel, the grinding power and the grinding ratio are high as compared with the case of the comparative grinding wheel (i.e., conventional grinding wheel incorporating the non-thermally-treated cBN abrasive grains). For each of the invention grinding wheel (Example 1) (i.e., grinding wheel incorporating the thermally-treated cBN abrasive grains) and the comparative grinding wheel (Comparative Example 1), the number of cBN abrasive grains remaining on the surface of the grinding wheel which had been used for grinding; i.e., the number of residual abrasive grains, was measured under a microscope within a field of view having the same area. As a result, in the case of Example 1, the number of residual abrasive grains was found to be large, and the number of voids remaining on the metallic coating layer as a result of falling of the cBN abrasive grains from the layer; i.e., the number of voids on the metallic coating layer, was found to be small, as compared with the case of Comparative Example 1.

[0020]

(Example 2)

As was clear from the above results, in the case of the invention grinding wheel incorporating thermally treated cBN abrasive grains, falling of the cBN abrasive grains was suppressed, as compared with the case of the conventional grinding wheel incorporating the non-thermally-treated cBN abrasive grains. Therefore, on the expectation that a grinding wheel incorporating a smaller amount of cBN abrasive grains would exhibit grinding performance comparable to the conventional grinding wheel, a grinding wheel in which concentration was reduced by 20% (from 75 to 60) was produced, and the thus-produced grinding wheel was subjected to grinding test. The grinding test was performed under the same conditions as those for the case of Example 1, except that the incorporation amount of cBN abrasive grains was reduced. The compositional proportions of the grinding wheel are shown in Table 3. The grinding test results are shown in Table 4. The dimensions or other factors of the grinding wheel of Example 2 are the same as those of the grinding wheel of Example 1, except that concentration is 60.

[0021]

[Table 3]

	Material	Compositional proportions (vol%)
Abrasive grains	Metal-coated cBN abrasive grains	24.9
Bond	Phenolic resin	65.1
Filler	Electrofused alumina #600	10.0

[0022]

[Table 4]

Abrasive grains	Example 2
Grinding ratio	150
Grinding power (W)	846
Number of residual abrasive grains	403
Number of voids on metallic coating layer	91

[0023]

Even when the amount of the cBN abrasive grains was reduced by 20%, the invention grinding wheel incorporating the thermally treated cBN abrasive grains exhibited grinding performance comparable to that of the conventional grinding wheel incorporating the non-thermally-treated cBN abrasive grains.

[0024]

[Effects of the Invention]

According to the present invention, there can be formed, on the surfaces of cubic boron nitride abrasive grains, a metallic coating layer exhibiting high bonding strength to the grains within a short period of time and at low cost. In addition, there can be provided a grinding wheel

incorporating the abrasive grains, which exhibits excellent grinding performance and has a long service life.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 schematically shows the appearance of a cBN abrasive grain which has not undergone thermal treatment.

[Fig. 2]

Fig. 2 schematically shows the appearance of a cBN abrasive grain which has undergone thermal treatment.

[Fig. 3]

Fig. 3 is a perspective view showing a cBN abrasive grain having, on its surface, crack-like grooves, the surface of the grain being coated with a metallic coating layer.

[Fig. 4]

Fig. 4 is a schematic cross-sectional view of the cBN abrasive grain of Fig. 3, as taken along line A-A'.

[Fig. 5]

Fig. 5 is an enlarged view showing a region of the abrasive grain into which the metallic coating layer intrudes.

[Fig. 6]

Fig. 6 is an SEM image showing a cBN abrasive grain which has undergone thermal treatment.

[Fig. 7]

Fig. 7 is an SEM image showing a region of the abrasive grain into which a metallic coating layer intrudes.

[Fig. 8]

Fig. 8 is an SEM image showing the surface of a cBN

abrasive grain which has undergone etching by use of a chemical.

[Description of Reference Numerals]

1. (111) plane
2. Growth plane
3. Groove
5. Metallic coating layer
10. cBN abrasive grain